Figure 4-31 - Sacramento at Holy Moses center braid

Hydrology –Criteria

Drainage reports for the project area are subject to the Mohave County Criteria. Officials in the Flood Control Department defined the criteria as the same listed in the Arizona Department of Transportation Highway Report Number: FHWA-AZ93-281, Drainage Design Manual, Hydrology, Final Report, March 1983, rev. 8-11-94 (ADOT) and the Maricopa County Criteria Manual. All drainage reports will need to be stamped by a registered Arizona Professional Engineer.

The Rational Method may be used up to 20 acres. HEC-1 models are evaluated as 100-year 6-hour storms for areas up to 20 square miles. The precipitation distributions are interpolated from six curves according to the total watershed area. All calculations must be verified with one of three approximation methods.

Initial basin hydrographs are developed using local rainfall, land use, and soil parameters within the Drainage Design Management System for Windows (DDMS) developed for the Flood Control District for Maricopa County. Total watershed areas up to 20 square miles are evaluated as local storms using the 100-year 6-hour precipitation amounts corrected according to the area-depth curves. The rainfall distribution curve is interpolated from six distribution curves according to the relationship with the total watershed area. Watershed areas from 20 square miles to 100 square miles are evaluated both as local storms as described above and as general storms which use a set distribution and 100-year 24-hour precipitation.

Soils

Soils information is taken from the General Soil Map for Mohave County, Arizona, prepared by the U.S. Department of Agriculture, Soil Conservation Service, dated January 1974. The soils for the area are listed in Table 4-2.

Table 4-2 Soils

MUID	SOILS NAME	HYDGRP
	Anthony-Vinton-Agua association	B
	Cave association	D
	Cellar-House Mountain-Rock outcrop association	D
	Barkerville-Gaddes-Rock outcrop association	C

Existing Hydrology

Drainage basins were delineated from the US Geological Survey 1:24000 scale Quad Maps for Arizona. Drainage through Rhodes Parcels and the Holy Moses wash area from Interstate 40 to the project site was verified using 2-foot aerial topography.

Parcel areas with the upstream watershed areas were used to determine approximate runoff affecting the site parcels. Subbasins were delineated to represent the major washes within the flood zones as determined by FEMA. Table 4-3 summarizes the pre developed drainage basin runoff for the three rainfall events studied. Junctions or concentration points are also identified. Runoff flow at the concentration points have depth/area reduction factors applied to the upstream drainage areas.

HEC-RAS Analysis for Holy Moses Wash and Diversion Washes

Since the Holy Moses Wash splits into four separate washes, this area was evaluated separately both for the local storm on its separate watershed and the general storm using the entire Golden Valley watershed.

Holy Moses Wash travels in a westerly direction from the apex of an alluvial fan formed at the base of the southern tip of the Cerbat Mountain Range and US Highway 66 (See Figure 4-32). The channel is well defined until it reaches the broad plain of the fan where surface features show multiple diversion channels and braided washes.

This analysis is performed to determine the probable flow characteristics and capacity of the three major diversion washes leaving the main Holy Moses Wash channel. The area under consideration is approximately 18,000 feet of the upper most reach of the wash as it leaves the fan apex. The three diversion washes are located at

approximately 1,700 ft, 10,400 ft, and 13,700 ft from the apex and are identified respectively as Diversion Washes 3, 2, and 1, respectively.

Methodology

The peak 100-year, 24-hour peak discharge was established using the Army Corp of Engineer's Hec-1 hydrologic program and the State of Arizona, DOT's Hydrology Manual and Mohave County for input parameters. The 100-yr, 24-hr rainfall is used to evaluate the overall effect a regional storm would have on the Golden Valley drainage shed (shed area approximately 147 square miles). The peak discharge at the fan's apex is approximately 22,300 cfs. Additional runoff flow was added midway along the wash to provide for tributary inflow.

COE's water surface program Hec-RAS was used to analyze flow characteristics within the channel sections.

Approach

Surface topography was obtained from aerial survey information and a digital terrain surface was generated. Cross-sections for the Hec-RAS analysis was generated from the digital surface and input into the model. Cross-sections were spaced at 250 ft intervals along the washes' main channel. Cross-sections were also developed for each of the three diversion channels.

Within the majority of the model's cross-sections, many of the sub channels and surface irregularities were blocked (program's obstruction capability) to force runoff into the main and secondary channels. This process was validated by use of an aerial photo to confirm runoff flow and the logic of flow in the secondary channels.

The model was run at the peak design flow to determine locations where runoff exceeds channel capacity. These locations were compared closely to the aerial photo of the wash for physical verification of diverted flow. More than three locations of out flow were observed, but they attribute to mainly minor losses of runoff and in many instances returned to the main channel.

The water surface elevations from the models output were compared to the channel bank elevation. Where the water surface exceeded the bank elevation, runoff spills out of the main channel and into either a secondary channel or leaves the wash in one of the diversion washes. Again, this was verified with the aerial photo. If the runoff left the Holy Moses Wash the flow amount was determined from the programs out of channel report and removed from additional downstream computation. Results of the HEC-RAS analyses are shown in Table 4.3.

Table 4-3 Channel Flow (cfs)

Location (Station)	Description	Flow (Main Channel)	Flow (Diversion Wash)
277+50	Apex (JHM5)	22,333	
260+00	Upstream	22,261	
	Diversion 3	19,857	2,476
210+00	Tributary Flow	20,228	
175+00	Diversion 2	17,056	5,484
140+00	Diversion 1 (JHM4)	15,950	1,106

Local Storm - 100-yr, 6hr Analysis

The Hec-RAS model was rerun for the 100-yr, 6-hr flow per the Hec-1 model. Results are shown in Table 4-4. The 100-yr, 6-hr rainfall (local storm) is applied to only the Holy Moses watershed, upstream on the Junction node HM4 (drainage area 69 square miles). The Holy Moses Basin Boundary Figure 4-32, shows the Station locations.

Table 4-4 Channel Flow (cfs)

Location (Station)	Description	Flow (Main Channel)	Flow (Diversion Wash)
277+50	Apex (JHM5)	9,255	
260+00	Upstream	9,178	
	Diversion 3	8,182	996
210+00	Tributary Flow	8,235	
175+00	Diversion 2	6,237	1,998
140+00	Diversion 1 (JHM4)	5,967	270

Table 4-5 - summarizes the 100-year 6-hour (local storm) and 24-hour (general storm) flows for the entire watershed.

Table 4-5 - Runoff Flows

Drainage Shed	Area (sq mi)	100-yr, 6-hr (cfs)	100-yr, 24-hr (cfs)
HM-A	40.60	2748	12960
HM-B	10.35	1076	5235
HM-C	14.58	1091	5175
JHM5	65.53	4843	22333
HM-D	3.90	513	2610
JHM4	69.43	4647	20597
13M-2A	4.30	722	4037
13M-2B	2.34	440	2641
13M-2C	4.40	701	3837
13M-2D	9.70	1164	4980
13M-3	9.30	1185	5966
13M-4	0.25	61	396
J13M-F	30.29	2238	17898
13M-1A	3.90	644	3586
13M-1B	3.60	508	2631
13M-1C	2.50	299	1489
J131C1	10.00	988	6685
J13M-E	40.29	2252	20520
C-2A	3.30	597	3520
C-2B	6.00	1375	3428
C-2C	3.80	401	1953
JC2C1	13.10	978	7496
J13M-D	53.39	3072	25511
C-1A	7.10	904	4554
C-1B	4.20	377	1807
C-1C	4.90	357	1689
JC1C1	16.20	1196	7401
J13M-C	69.59	3944	26847

Basin Parameters

Table 4-6 identifies the rainfall depths taken from the isopluvial map in the ADOT manual for the following events:

Table 4-6 Precipitation

	2-year	100-year
6-hour	1.2	3.2
24-hour	1.4	4.2

Rainfall depths for the 2-year to 500-year precipitation events with durations from 5-minute to 24-hour are calculated within the DDMS program.

Depth-area reduction factors were applied to the HEC-1 modeling to distribute or average the rainfall depth over the large drainage shed. These factors were interpolated from Tables 2.1 and 2.2 of the Drainage Design Manual for Maricopa County, Hydrology Volume, and Chapter 2-Rainfall.

Infiltration loss was calculated using the Green and Ampt method. The predominant soil type was identified as Anthony-Vinton-Agua Association. They are typically a sandy loam exhibiting the following characteristics as shown in Table 4-7 (See ADOT, Table 3-2):

Table 4-7 Soil Characteristics

Soil Texture	DTHETA			XKSAT	PSIF	IA
	Dry	Normal	Saturated	In/hr	Inches	Inches
Sandy loam	0.35	0.25	0	0.4	4.3	0.35

Soil data from within the default values of the DDMS program was chosen that typified the same soil characteristics as the project soils. Normally, soils of desert cover are considered “dry”, where irrigated soils are “normal”. Where exact default soil types were not identified, the parameters were modified prior to running the program.

The drainage basins were identified to have a typical desert type land use. This was included within default parameters of the program and pre project conditions were determined to be “dry”.

The basic naming convention of the basins for the exhibits and model are Holy Moses Wash=HM, Thirteen Mile Wash=13M, Cerbat Wash=C, and Sacramento Wash=S. Multiple braids of the washes are identified with a sub text number. The following letter represents a sub-basin within the wash’s basin (i.e., Sub-basin A within Cerbat Wash tributary 1, C-1A). Table 4-8 shows the characteristics used in the development of the basin hydrographs.

Table 4-8 Basin Characteristics

Sub-Basin	Area	Length (mi)	Slope (ft/mi)	Lca (mi)	Tc[1]	RTIMP
HM-A	40.60	13.1	216.9	5.3	3.42 hr	0.00%
HM-B	11.50	6.3	210.9	3.1	2.21 hr	0.00%
HM-C	9.50	9	104.9	4	2.90 hr	0.00%
13M-4	0.25	0.6	100	0.3	0.54 hr	0.00%
13M-3	9.30	5.5	100.5	3.5	2.50 hr	0.00%
13M-2A	4.30	2.8	462.9	1.5	1.16 hr	0.00%
13M-2B	2.34	2.2	317.5	0.8	0.95 hr	0.00%
13M-2C	4.40	3.3	149.5	1.4	1.50 hr	0.00%
13M-2D	9.70	7.5	199.5	2.6	2.19 hr	0.00%
13M-1A	3.90	3.3	515.2	1.4	1.16 hr	0.00%
13M-1B	3.60	3.6	240	2	1.49 hr	0.00%
13M-1C	2.50	4.5	145.5	2.2	1.72 hr	0.00%
C-2A	3.30	2.6	423.1	1.1	1.05 hr	0.00%
C-2B	6.00	4.3	116.3	2.3	1.97 hr	0.00%
C-2C	3.80	4.6	65.2	2.3	2.15 hr	0.00%
C-1A	7.10	4.5	433.3	3.1	1.68 hr	0.00%
C-1B	4.20	5.7	61.4	2.8	2.43 hr	0.00%
C-1C	4.90	6	23.3	3.1	3.11 hr	0.00%

1 $Tc=2.4A^{0.1}L^{0.25}Lca^{0.25}S^{-0.2}$ (ADOT Equation 4.1)

Routing of the basins and sub-basins was initially developed within the DDMS program, though the program does not place routing in the proper sequence. Sequencing and placement of basin routing was accomplished using Microsoft Word Pad as a text editor. The program developed the local basin hydrographs, but the model was run using the Corp. of Engineers, HEC-1 program. Table 4-9 shows the routing parameters used to convey the basin and junction flows through the system. It is assumed that routing is performed using Kinematic Wave Routing methods within a trapezoidal channel. The Manning Roughness Coefficient “n” used in natural channels is 0.035.

Routing convention for exhibits and table identifies the Basin (HM, 13M, C, or S), Routing “R” identified at the beginning of the description shows direction by identifying the upstream junction or node, with the flow direction downstream. Where no direction is given, it refers to a terminal reach before it converges with another wash. Junction nodes are represented by the letter “J” at the beginning of the description.

Table 4-9 Routing

Routing	Distance (ft)	Elevation (ft)	Slope (ft/ft)
RJHM1	7935	55	0.0069
RJHM2	1028	10	0.0097
RJHM3	6804	55	0.0081
RJHM4	9956	105	0.0105
RJHM5	25753	290	0.0113
RHMC	4174	40	0.0096
RHMB	17259	410	0.0238
R13MA	3440	30	0.0087
R13MB	2901	20	0.0069
R13MC	3047	20	0.0066
R13MD	1428	10	0.0070
R13ME	3662	40	0.0109
R13MF	2412	153	0.0634
RJ1331	921	5	0.0054
RJ13C1	24401	330	0.0135
R13M1A	18487	470	0.0254
RJ13D1	2679	15	0.0056
RJ13C2	9309	50	0.0054
RJ13MC1	12300	300	0.0244
R13M2A	15094	450	0.0298
R13M3B	25487	650	0.0255
RJC1B1	31713	350	0.0110
RC1A	30090	510	0.0169
RJC2C1	3957	20	0.0051
RJC2B1	24401	300	0.0123
RC2A	22777	480	0.0211

Developed Hydrology

Table 4-10 - summarizes the site post developed drainage basin runoff for the three rainfall events studied.

Table 4-10 Runoff Flow

Sub-Basin	Area (sq mi)	100-yr, 6-hr	100-yr, 24-hr
JHM-4	69.43	4647	20597
HM-UPA	2.67	1052	2008
JUPA1	72.10	4086	18227
HM-UPB	1.18	800	1796
JUPB1	73.28	4181	18330
J13-ME	40.29	2252	20520
13MUPB	0.3	141	208
J13M-D	53.73	1242	25511
13UPA	3.10	1130	1731
13MUPC	0.37	241	633
J13M-C	69.92	3944	26847
J13M-B	73.29	4325	27876
13MUPD	0.7	422	938

No upstream detention assumed.
Upstream detention assumed

The developed drainage basins are based on the proposed land use schedule as shown on Figure 4-33 (Golden Valley – South Concept 'K' Sheds). Basins with the sub script UP refer to the Land Use plan within each major 'wash shed. The A to C sub script refers to the sub-basin. Table 4-11 shows the basin parameters used to develop the shed's runoff hydrograph.

Table 4-11 Basin Parameters

Sub-Basin	Area (mi^2)	Length (mi)	Slope (ft/mi)[1]	Lca (mi)	Tc[2]	RTIMP
HMUPA	2.67	2.7	52.8	1.1	1.57 hr	31.48%
HMUPB	1.13	1.2	52.8	0.6	1.01 hr	72.65%
13MUPA	3.10	8.4	52.8	1.4	2.25 hr	51.23%
13MUPB	0.30	0.8	52.8	0.4	0.72 hr	47.67%
13MUPC	0.36	0.8	52.8	0.2	0.62 hr	67.36%
13MUPD	0.73	1.2	52.8	0.4	0.88 hr	56.03%

Conveyance slope assumed at S=0.01ft/ft
Tc=2.4A0.1L0.25Lca0.25S-0.2 (ADOT Equation 4.1)

Storm Drain Facilities

The storm drainage facilities were estimated using the Land Plan K from RVI. Two alternatives were considered, with a detention basin along the north boundary (Table 4-12) and without (Table 4-13). Storm drain facilities along the Aztec Corridor were not considered in this study.

The storm drainage detention basin proposed at along the northerly boundary of the site is designed to store the volume of runoff generated from the 100-yr, 2-hr rainfall event (approximately 500 acre-feet) from the Thirteen Mile Wash and the Holy Moses northern braid. The release rate from the proposed outlet structure (similar to a 2-12x6 box outlet structure) is approximately 1,300 cfs, equal to the peak flow from the 100-yr, 2-hr storm event. This flow is joined with the Cerbat Wash for a channel flow of 9285 cfs. This flow is shown on Summary Tables 4-12 and 4-13 as the Thirteen Mile Wash. The 96-inch RCP collects the flows along the east side of the site

Table 4-12 Storm Drain w/Detention Basin

Description	Quantity	Unit	Unit Cost	Total
Thirteen Mile Wash Riprap Trap. 320 w/4:1 side slope	12460	LF	$1,800	$22,428,000
Thirteen Mile Crossings	2	Each	$1,082,250	$2,164,500
Detention Basin	1	Each	$4,175,253	$4,175,253
Holy Moses Wash Concrete Trap. 250 w/2:1 side slope	17070	LF	$1,302	$22,225,140
Holy Moses Crossings	1	Each	$2,46,0500	$2,460,500
Misc. Storm Drain 96" RCP	5400	LF	$374.85	$2,024,190
Sacramento Wash conc Rect. 250x7.5	5400	LF	$3,028.5	$16,353,900
			Total	$71,831,483

Table 4-13 Storm Drain w/o Detention Basin

Description	Quantity	Unit	Unit Cost	Total
Thirteen Mile Wash Conc. Rect. 212x6	12460	LF	$2,565	$31,959,900
Thirteen Mile Crossings	2	Each	$2,094,560	$4,189,120
Holy Moses Wash Concrete Trap. 250 w/2:1 side slope	17070	LF	$1,302	$22,225,140
Holy Moses Crossings	1	Each	$2,46,0500	$2,460,500
Misc. Storm Drain 96" RCP	5400	LF	$374.85	$2,024,190
Sacramento Wash Conc. Rect. 250x7.5	5400	LF	$3,028.5	$16,353,900
			Total	$79,212,750

Phase I – Golf Course Improvements

One of the initial development areas within the Phase I project scope is to construct the proposed golf course (See Figure 4-34). The east side of the Golf Course needs to be protected from stormwater runoff generated from the south tip of the Cerbat Mountains. Additional runoff flow from the divergence channel of the Holy Moses Wash also impacts the golf course area.

The drainage shed affecting the easterly boundary of the project site, between the Holy Moses Wash and the northeast property corner consists of approximately 2.03 square miles. For the purpose of this analysis, the drainage shed is subdivided into four smaller sub-sheds which is bounded along the south by the Holy Moses Wash and to the north by its divergent channel. Runoff from Sub-shed GCA flows naturally flows north of the golf course. Runoff from Sub-shed GCB is deflected from the golf course by a perimeter road whereas, the divergent channel of the Holy Moses Wash and tributary areas of Sub-shed GCC flow directly into the golf course. Sub-shed GCD is a smaller in area and has minimal impact to the course.

Table 4-14 gives a summary of the drainage shed characteristics imparting the golf course and runoff flow from those sheds.

Table 4-14 – Golf Course Characteristics

Sub-Basin	Area (mi2)	Length (mi)	Slope(ft/mi)	Lca (mi)	Flow
GCIA	0.847	3.435	71.8	2.04	597
GCIB	0.330	2.584	71.8	1.20	289
GCIC	0.758	2.510	71.8	1.18	664
GCID	0.091	1.119	71.8	0.37	116

Conveyance slope assumed at S=0.0138ft/ft

$Tc=2.4A^{0.1}L^{0.25}Lca^{0.25}S^{-0.2}$ (ADOT Equation 4.1)

Costs for this area would be the 96-inch RCP, the Holy Moses Wash and the Holy Moses Crossing. This cost for Phase I would be $6,709,830.

Conclusions

The total cost for the storm drainage control can exceed $79 million. Construction of the detention basin will lower the total cost by approximately $7 million.